THE TONOSCOPE AS A MEANS FOR REGISTERING COMBINATION TONES[1]

By Evelyn Gough and Genevieve Robison

The possibility of producing and demonstrating combination tones in the mass of air was clearly established by Helmholtz.[2] He found that the essential condition for the generation of strong objective combination tones was that the same mass of air should be violently agitated by two generating tones simultaneously. The siren and the harmonium, each of which possesses a common wind chest in which the air is set in vibration by all notes played upon it, produced objective combination tones which were extremely powerful.

The presence of the combination tones in the air was demonstrated by the use of vibrating membranes and resonators adjusted to be in unison with these tones. Helmholtz found in using the harmonium that when the two generators were supplied by air from different bellows the objective part which the resonators reinforced was much weaker. When no common air chamber or mechanical connection existed for the two tones, as in the case of tones from two singers, two separate wind instruments, or two violins, the reinforcement of the combination tones by resonators was small and dubious. In such cases the combination tones, which might be clearly audible, he believed to originate, from vibrations in the ear, either in the tympanic membrane or in the ossicles of the middle ear.

Apparatus and Method

The present paper reports experiments showing that the Seashore tonoscope has certain unique advantages as an apparatus for the objective demonstration of combination tones.[3] A description of the apparatus employed may throw light on the results. An early model of the tonoscope driven by a synchronous motor at a speed regulated by a 10 v. d. tuning fork was available. It was energized by a commercial alternating current. For controlling the strength of current closely the rheostat furnished with the tonoscope was supplemented by electric lamps. A manometric capsule, designed with special view to effectiveness with the high pitches of female voices, was substituted for the standard piece. It differs from the standard in certain respects. The capsule is much smaller, the membrane being 12.5 mm. in diameter. The gas supply is admitted at relatively high pressure through a small inlet (.25 mm. in diameter). A relatively large tube (2 mm. in diameter) leads from the gas chamber to the flame tip. The flame tip is one of the small-sized tips which are used on small acetylene hand lights. A gas cock makes possible fine adjustments of the flame.

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[2] Helmholtz, Sensations of Tone, pp. 152-159.

[3] Seashore, The Tonoscope, Psychol. Monog., No. 69, 1914, XVI, 1-12.

Ordinary dental dam is used for the membrane. For the purpose of this particular experiment a rubber voice tube 30 cm. long was employed. It was stopped at the end with a cork and sealed. In opposite sides of this tube were inserted two smaller tubes with tin funnels at their free ends for mouth-pieces.

Two tones sung simultaneously into the branches of the voice tube evidently move along a common air passage to the membrane and through it are communicated to a gas chamber and a flickering flame in turn. In passage they strongly agitate a common air chamber, a common gas chamber, the rubber walls of a common voice tube, and a loosely stretched membrane, any one of which would, perhaps, be capable of adding combination tones to two primary tones which are made to vibrate through it.

The purpose of this experiment has been to discover whether or not with this apparatus it is possible to get distinct readings on the tonoscope for vibration rates of tones formed by the combination of two tones sung simultaneously into the voice tube, which are wholly different from the readings produced by either tone sung alone.

The inquiry has so far been confined to difference tones of the first order and summation tones of the first order. Pairs of pitches were selected which could be sung easily and read plainly from the tonoscope, and whose difference or summation tones, if they appeared, would also possess vibration rates within the effective range of this instrument. Variously pitched tuning forks gave the objective pitches which the singers attempted to duplicate at each trial. Each of the two tones was sung and recorded separately, then they were sung together, and a complete reading was taken.

RESULTS

			Pitch from Tuning Fork	Tonoscope Readings
1	Generators	a^1	440 v.d.	146 x 3 = 438 v.d.
				219 x 2 = 438 v.d.
		c^1	264 v.d.	132 x 2 = 264 v.d.
	Difference Tone	f		174 x 1 = 174 v.d.
2	Generators	g^1	396 v.d.	196 x 2 = 392 v.d.
				131 x 3 = 393 v.d.
		b	247½ v.d.	125 x 2 = 250 v.d.
	Difference Tone	d		142 x 1 = 142 v.d.
3	Generators	g^1	396 v.d.	192 x 2 = 384 v.d.
				128 x 3 = 384 v.d.
		a	220 v.d.	110 x 2 = 220 v.d.
	Difference Tone	f		164 x 1 = 164 v.d.
4	Generators	f^1	352 v.d.	175 x 2 = 350 v.d.
				117 x 3 = 351 v.d.
		a	220 v.d.	110 x 2 = 220 v.d.
	Difference Tone	c		131 x 1 = 131 v.d.
5	Generators	b	247½ v.d.	124 x 2 = 248 v.d.
		g	198 v.d.	196 x 1 = 196 v.d.

RESULTS—Continued

		Pitch from Tuning Fork	Tonoscope Readings
Summation Tone	(a^1+)		(Theoretical position at 148 x 3 = 444 v.d.) None observed
6 Generators	a	220 v.d.	114 x 2 = 228 v.d.
	f	176 v.d.	171 x 1 = 171 v.d.
Summation Tone	(g^1)		(Theoretical position at 199 x 2 = 398 v.d. 133 x 3 = 399 v.d.) None observed

With the manometric capsule which was employed in these tests tones whose vibration rates lie within a range of the first, second, and third, multiples of the dot frequencies on the tonoscope are easily read. The patterns corresponding to the different dot frequencies, however, are distinctly different in appearance. Pitches which coincide in rate with a dot frequency within the range of the tonoscope give strong contrasts and bring out the dots in much elongated form and at the same distances apart that they hold on the stationary drum. Those which correspond to multiples of the dot frequencies cause the dots to appear with degree of contrast, separation and elongation which are in inverse proportion to the multiple numbers.

Readings for the difference tones were easily gotten in the tests, and where the generator tones were so chosen as to give difference tones within the range for direct reading, the dots representing these tones stood out with striking clearness. In fact, where the generator tones corresponded to multiples of dot frequencies while the difference tones coincided with them in rate, as in the four illustrations given in the table, the dots representing the difference tones were generally clearer than those representing the generator tones. The correspondence between the tonoscope readings for the generator tones and the vibration numbers engraved on the forks from which the pitches were taken was only approximate. The readings for the difference tones, however, coincide exactly with the calculated differences between the readings for the generators.

The results from the summation tones were entirely negative, no readings corresponding to the summation numbers appearing on the screen, although strong primary tones whose summation effect could have been recorded if sufficiently pronounced were used. Modifications in the apparatus favoring the higher tones or the use of lower primary tones might possibly lead to a different outcome.

In summary: The Seashore tonoscope furnishes a means for the demonstration of difference tones which possesses the following distinct merits. The apparatus furnishes conditions favorable for the generation of strong objective difference tones. Clear visible evidence of the difference tones is present. Objective visible readings are produced for each primary tone separately, and for the difference tone and both generating tones simultaneously. A practically untrained observer can record readings for the three tones accurate to one or two vibrations a second.

References:

1. Helmholtz, H. L. F. Sensations of Tone. Tr. by A. J. Ellis, 1895.
2. Seashore, C. E. The Tonoscope. Psychol. Monog., No. 69, 1914, XVI, 1-12.